# Generation  X -  Attitude Control System (ACS)

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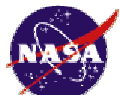**Josephine San**

# ACS Overview

◆ Requirements

◆ Assumptions

◆ Disturbance Torque Assessment

◆ Component and Control Mode Recommendations

◆ Major ACS Issues and Concerns
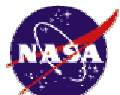
◆ Recommended Trade Studies

◆ Risk Assessment

# ACS Requirements

♦ **Pointing Requirements**

- Boresight Pointing Accuracy:         < 1 arc-second
- Boresight Pointing Knowledge:       0.5 arc-sec
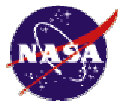- Drift or jitter:                                < 1 arc-sec/minute

# ACS Assumptions

- **Coordinate System:** origin at center of mass
- X toward sun, Y transverse, +Z toward detector
- **Moments of Inertia (kg-m$^2$)**

|  | Stowed | Deployed |
|---|---|---|
| X | 13320 | 680000 |
| Y | 13320 | 680000 |
| Z | 22500 | 22500 |

- **Effective Area** 30 m$^2$
- **Low-earth Orbit:** altitude = 400 km, Inclination: = 51 degree
- **Science Orbit:** L2
- **Science Attitude** +X pointed near the sun. Boresight pointing
- restricted to 0.0 +/- 15 deg from the sun.

# Attitude Geometry



Boresight

+Y

+X

+Z

+/- 15 º
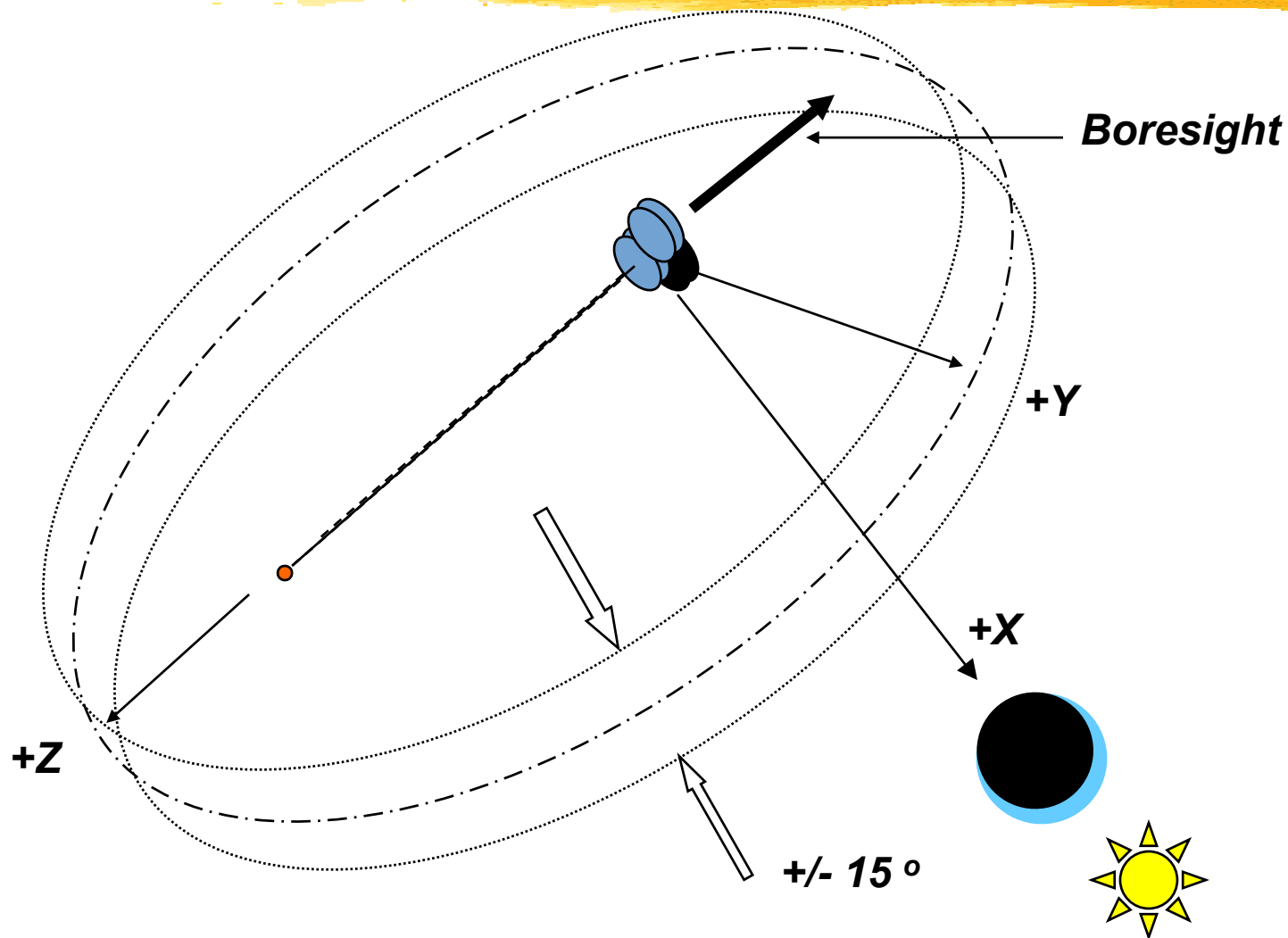
# ACS Disturbance Torque Assessment

- **Gravity Gradient Torque at LEO:**
    - With Boom stowed:          0.017   Nm
    - With Boom Deployed:      1.200   Nm
    - (at L2 gravity gradient is negligible)

- **Aerodynamic Torque at LEO:**
    - With Boom stowed:        0.012   Nm
    - With Boom Deployed:     0.292   Nm

- **Solar Pressure at L2**
    - Torque:
        - With Boom stowed:      $1.4 \times 10^{-6}$ Nm
        - With Boom Deployed:   $1.0 \times 10^{-3}$ Nm
    - <u>Momentum buildup</u> per day:
        - With Boom stowed:      0.12 Nms
        - <span style="color:red">With Boom Deployed:    86.5  Nms</span>

# ACS Component Recommendation

| Components | Model | Quantity | Cost ($K) | Mass (Kg) | Power Orbit Avg (W) | Power Peak (W) |
|---|---|---|---|---|---|---|
| ACE | (Based on Map) | 2 | 2000 | 16 | 22 | 26 |
| Coarse Sun Sensor | Adcole 11866 | 8 | 48 | 0.0368 | 0 | 0 |
| Digital Sun Sensor | Smex lite, 40560 | 2 | 400 | 1.76 | 1.4 | 1.4 |
| IRU | Litton SIRU | 1 | 1000 | 5.44 | 22 | 40 |
| Star Tracker | CT-602 | 2 | 13000 | 11.804 | 0 | 10 |
| Reaction Wheel | Explorer, in house | 4 | 1600 | 70.92 | 28 | 440 |
| | | **Total =** | **18048** | **105.961** | **73.4** | **517.4** |
| | | | | | | |
| | | | | | | |
| | | | | | | |

◆ Based on current technology meeting mission requirements

◆ Future technology should enhance performance
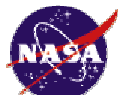
# ACS Component Placement

- ◆ Wheel should be located as close to the center of mass as possible to reduce wheel induced jitter
- ◆ Four wheels can be arranged in a pyramid to provide "boosted" torque in the major slewing axis as well as redundancy.
- ◆ Star tracker and gyros should all rigidly mounted with respect to the critical alignment surface.
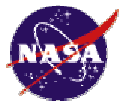
# ACS Control Mode Recommendation

♦ **Rate null/Sun acquisition -** Null the rate and point solar array normal to the sun.

♦ **Delta H mode -** Perform delta H to unload wheel momentum

♦ **Delta V mode -** Slew to burn position and perform delta V

♦ **Science mode -** 3-axis stabilized with boresight axis (Z) perpendicular to sun-spacecraft line (ecliptic plane) +/- 15 degrees, use reaction wheels for slewing and pointing.

♦ **Safehold mode -** Use CSS and wheel to point solar array normal to the sun, similar to sun acquisition
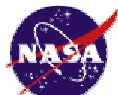
# ACS Issues and Concerns

♦ Boom bending due to thermal loads and vibration.

♦ Non-collocated actuator and sensor in the pointing loop can be a source of instability, e.g., Sensing at the detector while moving the optics.

♦ Rotation of the entire spacecraft about the Z axis is directionally unstable in the presence of energy sinks.

♦ Symmetry of X and Y axis moment-of-inertia should be maintained to prevent oscillatory motion around Pitch axis.
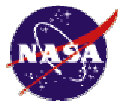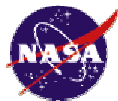
# ACS Options Considered

- Spinning the optics for thermal stability was considered

  - The large moment-of-inertia of the optics and an acceptable spin rate for thermal stability leads to an angular momentum too large for target-to-target maneuvering with wheels.

  - A large counter-rotating mass is a possible solution keeping the spacecraft zero momentum biased.
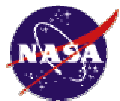
# ACS Recommendations for Future Study

♦ Detector on boom or separate spacecraft for detector

♦ Worse case two axis slews

♦ New technology wheel - larger rotor inertia and small dynamic and static imbalance

# ACS Risk Assessment

- Boom length adds complexity to mission
  - Solar pressure torques
  - Torsional bending
  - Non-collocated sensors and actuators
  - Interference of control bandwidths (0.1-0.05 Hz) and structural modes (~0.2 Hz)

- If Dual Spin utilized can create instability